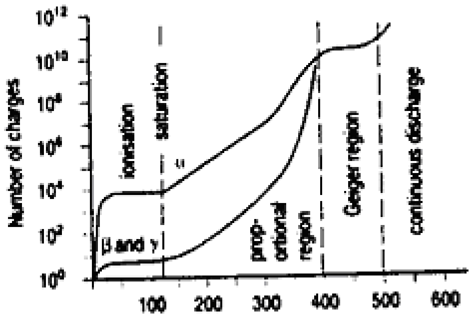
RADIATION COUNTERS

3.7.1 Ionization Methods (Gas Detectors)

The result of radiation interacting with a gas is commonly the production of ions , positively and negatively charged particles . These can be collected at electrodes if the potential difference is set up across the ionized material. If the applied voltage is low , many of these ions will recombine . As it increases a point will be reached when all those produced will be collected. This is known as "**saturation**", and the chamber is said to be operating in the " **ionization region** ".



Figure(3-5):Effect of increasing voltage on a gas ionization chamber .

The electrical current resulting from ths flow of ions is extremely low (about $\mathbf{10^{-12}}$ **A**) , but electronic circuit is known as a d.c. amplifier can be used to measure it . This current represents a mean value of the interaction of many charged particles or photon radiations. This type of device is called an **ionization chamber**.

As the voltage applied across the ionization chamber increases, the charge or current produced also increase, as shown in figure (3-5) . This is because the original ions are given sufficiently energy to cause secondary ionization of the gas molecules by colliding with them on the electrodes. This avalanche or gas amplification effect can increase the current greatly and make it possible to detect individual ionizing particles as pulses of current. Such an instrument is called a **counter**. At voltage above saturation the pulses are proportional to the energy of the original ionizing particle. The total charge in the current pulse now is proportional to the initial amount of ionization, and it indicates the energy of the ionizing particle that passed through the

detector. Often these current pulses are fed to a **multichannel analyzer**, which records the number of pulses produced versus the total charge in the pulse. This information can be used to identify the nuclide producing the radiation. If the applied voltage is increased, the counter operates in the **Geiger region**. Here each primary electron produces several secondary electrons, which in turn produce others, and so on. A current pulse develops that is large enough so that it can be observed or recorded with very simple circuits. Such a detector is called a **Geiger – Mueller counter**, and it can be quite compact and portable.

3.7.2 The Geiger Counter

You may be familiar with the structure and operation of the Geiger counter from your investigations of the properties of ionizing radiations. The counter does have some applications in medicine because its ability to measure very low activities. It also has the advantage of producing a stable, reliable output with no need for amplification, so the device can be small and portable. Its major disadvantage is the dead time during which it cannot register a pulse since it is recovering from the effects of the previous one. This about **1ms**, and so puts a severe limit on the maximum activity that can be accurately measured. Because it is rather insensitive to **γ radiation** it can be used to count charged particles in the presence of **γ radiation** . It is also used in the monitoring equipment to detect contamination. The counter has same structure like other ionization chambers . The gas is a mixture of inert gas and halogen gas " **quenching agent** " to reduce the dead time. The central wire is tungsten and the walls are metal or glass with inner conductive coating as a cathode. The operating voltage is usually between

500–1000 V figure (3-6) .

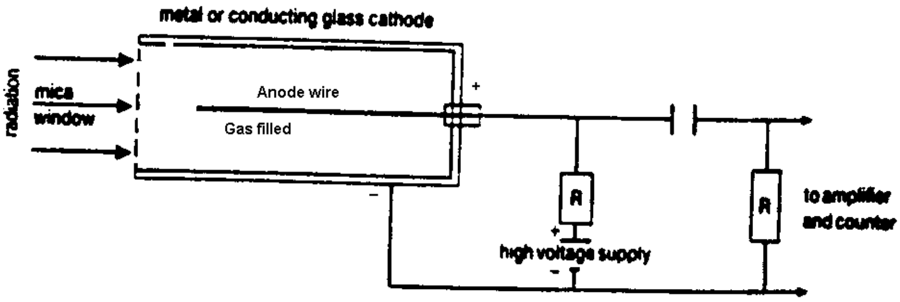
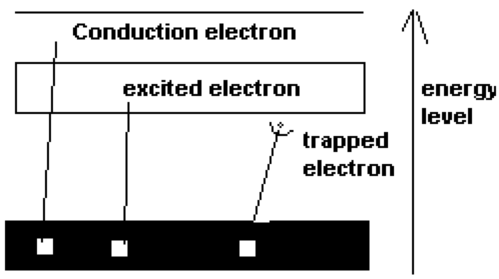


Figure (3-6): Gieger – Muller tube .

3.7.3 Solid state Detectors

The effect on many crystalline substance is to raise the energy of electrons in it . The highest level in which the electrons are normally exist is the **valence band** , above which there is a **forbidden band** . The transfer of energy may raise the electron through this to the **conduction band** or the **exciton band**, or the presence of **impurities** may give rise to the electron being trapped in the **forbidden band** figure (3-7). In the **conduction band** the electrons are free to migrate when a potential difference is applied. In the **exciton and forbidden bands** they are not, but the trapped energy can be realesed to provide a measurable signal. In the **exciton band** this occurs spontaneously, while in the

Forbidden band it must be simulated. Each of these effects give rise to detectors, like **scintillation** detector that will be discussed in the following section.

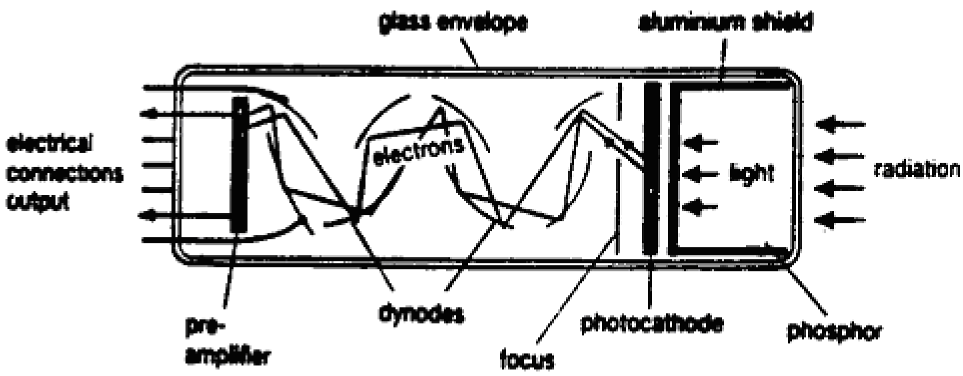


Figure(3-7):Electrons and energy bands (conduction , excitation and trapping)

3.7.3 Scintillation Counters

These operates on the same principle as fluoroscopy; the emission of light as an electron returns to valence band. In this case the purpose is to count the emissions or scintillations, and therefore measure the exposure. There are a number of scintillator materials in use including those in solution, and large organic molecular crystals, which are used for detecting **β** particles . Those are widely used are simple ionic crystals as zinc sulphide (to detect **α**) , lithium iodide (for thermal neutrons) and sodium iodide (for **γ**).

The effect of electron emission can be magnified with a photomultiplier tube . Light from the scintillator ejects electrons from a photocathode. This is a thin layer of semiconductor material coating the inner surface of the tube. Those photoelectrons are then accelerated and multiplied by a series of electrodes called dynodes held at increasingly positive potentials along the tube. The dynodes are made from an alloy like beryllium-copper which causes several secondary electrons to be emitted by the energetic incident electron. This process is repeated several times, causing multiplication each time. The electrons are collected by the anode and output through a further amplifier. The complete device is called a scintillation counter figure (3-8) , and it is able to amplify the original light output by a factor of between **10^5 and 10^8** , but strictly in proportion to the original energy . By using a multichannel pulse analyzer it is possible to obtain the energy spectrum of the incident radiation.



Figure(3-8): Scintillation detector .

The most common scintillator is sodium iodide, activated with about 0.5% thallium iodide and abbreviated as **Na(Tℓ)** . The substance is hygroscopic, so it has to be kept in sealed containers. These are usually made of aluminum, with a glass or quartz window which is coupled to the photomultiplier tube with silicon oil or grease. It has the advantages of:

- high efficiency in converting about 10% of the incident energy into light ,
- rapid scintillation ,
- excellent **γ** detection ability .

The scintillation counter has a widespread use in hospitals , as it can measure all types of radiation commonly encountered , with the selection of a suitable scintillator .